

New subgenera and a new species of the genus *Raphignathus* Dugès (Prostigmata, Raphignathidae), with taxonomic notes on the genus *Neoraphignathus* Smiley & Moser

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Abstract

Four new subgenera in the genus *Raphignathus* Dugès are hereby proposed: *Raphignathus* (*Raphignathus*), **subgen. nov.**, *Raphignathus* (*Monoraphignathus*), **subgen. nov.**, *Raphignathus* (*Diraphignathus*), **subgen. nov.**, and *Raphignathus* (*Triraphignathus*), **subgen. nov.**. These subgenera are diagnosed by the number of setae on the interscutal membrane of females. A new species, *R. (D.) neohecmatanaensis* sp. nov., is described and illustrated based on females collected from *Ziziphus spina-christi* Mill. (Rhamnaceae). The taxonomic status of the monotypic genus *Neoraphignathus* Smiley & Moser and three species (*R. evidus*, *R. hsiufui*, and *R. johnstoni*) are discussed. A key to world species of the family Raphignathidae is given.



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Introduction

Members of the family Raphignathidae Kramer (Prostigmata, Raphignathoidea) are active predators feeding on small arthropods (Meyer and Ueckermann 1989). They are mostly found in humus soil under dense bushes, leaf litter, lichens, and mosses and on a wide range of plants (Fan and Zhang 2005). Raphignathids have cervical peritremes and contiguous coxae and are divided into two genera: *Raphignathus* Dugès (76 species) and *Neoraphignathus* Smiley & Moser (one species, *N. howei* Smiley & Moser) (Smiley and Moser 1968; Khanjani et al. 2013). These genera are mainly differentiated by the presence and absence of dorsal shields, respectively. *Raphignathus* species have a worldwide distribution, whereas *Neoraphignathus* is only known from Louisiana, USA (Beron 2020).

The genus *Raphignathus* (type species: *R. ruberrimus* Dugés) was diagnosed as having three, or sometimes four, dorsal shields (Atyeo et al. 1961). While discussing the chaetotaxy of the superfamily Raphignathoidea, Atyeo et al. (1963) provided a general description of the genus *Raphignathus*. They considered the number of setae on prodorsal shields and on interscutal membrane as important taxonomic characteristics. In addition, the number of setae on the interscutal membrane was also used to differentiate among the species in recently published diagnostic keys (Nasrollahi et al. 2018; Pishehvar and Khanjani

2021). The validity of some *Raphignathus* species has been questionable due to ontogenetic development, and more females need to be collected and observed (Dönel and Doğan 2011). *Raphignathus broomicus* Podder was considered a species inquirenda due to uncertain and doubtful characters (Doğan and Erman 2019). Until now, most of published work on the family Raphignathidae has been regional and includes identification keys for China, India, Iran, and Turkey (Fan and Yin 2000; Doğan and Erman 2019; Pishehvar and Khanjani 2021).

In the present study, four new subgenera of *Raphignathus* are erected based on the prominent and consistent morphological character (number of setae on interscutal membrane). A new species, *R. (D.) neohecmatanaensis* sp. nov. is described and illustrated based on females. Some taxonomic notes on the monotypic genus, *Neoraphignathus* Smiley & Moser, and the identity of three species (*R. evidus*, *R. hsiufui*, and *R. johnstoni*) are concisely discussed. A diagnostic key to the world species is also provided.

Material and method

All published taxonomic literature on the family Raphignathidae was critically reviewed to confirm the validity of the species, subgeneric divisions and to prepare a diagnostic key of world species. The new raphignathoid species was collected by shaking foliage of *Ziziphus spina-christi* Mill. (Rhamnaceae) over a white sheet of paper; mite specimens were preserved in small vials containing 70% ethanol. The specimens were permanently mounted on glass slides in Hoyer's medium and identified under a phase-contrast microscope (BX51, Olympus, Tokyo, Japan). All measurements of the holotype specimen are given in micrometers (μm), followed by those of paratypes in the parenthesis. The terminology and abbreviations used in the description of the new species follow those of Kethley (1990) and Grandjean (1939, 1944, 1946). The holotypes and paratypes were deposited at the King Saud Museum of Arthropods (KSMA, Acarology section), Department of Plant Protection, College of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia.

Results

Four new subgenera of the genus *Raphignathus* are proposed: *Raphignathus* (*Raphignathus*), subgen. nov., *Raphignathus* (*Monoraphignathus*), subgen. nov., *Raphignathus* (*Diraphignathus*), subgen. nov., and *Raphignathus* (*Triraphignathus*), subgen. nov., on the basis of the number of setae on the interscutal membrane, a prominent and consistent morphological character. A new species, *R. (D.) neohecmatanaensis* sp. nov., is described and illustrated based on adult females. Furthermore, taxonomic notes on the status of the monotypic genus, *Neoraphignathus* Smiley & Moser, and the identity of three species (*R. evidus*, *R. hsiufui* and *R. johnstoni*) are discussed. A diagnostic key to the world species is also presented.

Family Raphignathidae Kramer, 1877

Raphignathidae Kramer, 1877: 215

Type genus. *Raphignathus* Dugès, 1834: 53

Diagnosis (based on Krantz and Walter (2009) and Fan and Zhang (2005)). Peritremes linear, not imbedded in dorsal surface of stylophore; paired peritremes running laterally from base of stylophore to make short loops in collar membrane between gnathosoma and podosoma; coxae II and III contiguous; stigmata opening at base of chelicerae.

Taxonomic divisions of the genus *Raphignathus*

The presence or absence of prodorsal shields are diagnostic for the differentiation of the two existing raphignathid genera. Atyeo (1963) discussed in detail the chaetotaxy of the superfamily Raphignathoidea while describing seven *Raphignathus* species. This author also provided comprehensive diagnosis of *Raphignathus* and stated that the number of setae on the shields and the interscutal membrane is a consistent and important diagnostic character. The number of setae on the interscutal membrane is considered to be a strong character and has been used in identification keys to distinguish species (Nasrollahi et al. 2018; Pishehvar and Khanjani 2021). Through our extensive study of the literature of all 76 *Raphignathus* species, we find that the number of setae on the interscutal membrane can be used to erect subgenera.

In the current study, we categorize species of the genus *Raphignathus* into four new subgenera based on the number of setae on the interscutal membrane. These four subgenera are *Raphignathus* (*Raphignathus*), subgen. nov. without setae (11 spp.), *Raphignathus* (*Monoraphignathus*), subgen. nov. with one seta (14 spp.), *Raphignathus* (*Diraphignathus*), subgen. nov. with two setae (33 spp.), and *Raphignathus* (*Triraphignathus*), subgen. nov. with three setae (10 spp.).

***Raphignathus* (*Raphignathus*), subgen. nov.**

<https://zoobank.org/4A81EA35-DC89-4971-BD24-0459A27A8621>

Type species. *Raphignathus ruberrimus* Dugès, 1834: 53.

Diagnosis. Interscutal membrane without setae.

Etymology. The subgeneric epithet refers to the nominotypical subgenus.

***Raphignathus* (*Monoraphignathus*), subgen. nov.**

<https://zoobank.org/D332A8E8-0390-4D39-95D4-A8C6E7E0B8D5>

Type species. *Raphignathus bathursti* Meyer & Ryke, 1960: 229.

Diagnosis. Interscutal membrane with one pair of setae.

Etymology. The subgeneric epithet refers to the one pair of setae on interscutal membrane.

***Raphignathus* (*Diraphignathus*), subgen. nov.**

<https://zoobank.org/0D7C8B12-10E8-4019-A2FA-591934FD9B17>

Type species. *Raphignathus gracilis* (Rack, 1962): 281.

Diagnosis. Interscutal membrane with two pairs of setae.

Etymology. The sub-generic epithet refers to the two pairs of setae on inter-scutal membrane.

The species included in this new subgenus are widely distributed over the world.

Raphignathus (Triraphignathus), subgen. nov.

<https://zoobank.org/80C632B9-6521-47BB-A6E2-3EA44EE761DD>

Type species. *Raphignathus domesticus* Shiba, 1969: 157.

Diagnosis. Interscutal membrane with three pairs of setae.

Etymology. The subgeneric epithet refers to the interscutal membrane with three pairs of setae.

Notes on the taxonomic status of the genus *Neoraphignathus*

To date, the family Raphignathidae has included two genera, *Raphignathus* and *Neoraphignathus*, which have been differentiated based on the presence or absence of shields on the dorsum. The monotypic genus, *Neoraphignathus* (type species: *N. howei* Smiley & Moser) was erected in 1968, based on a single female holotype specimen without detailed description and illustration. Based on observations and the collection of the immature specimens of the genus *Raphignathus*, prodorsal shields are weakly developed or absent in immatures. Atyeo et al. (1961) has reported that dorsal shields are sometime feebly developed. Since its first description, the type species, *N. howei*, has not been redescribed, nor have new *Neoraphignathus* species been described. We suggest that the type specimen of *N. howei* be re-examined and also that more specimens be collected from the type locality to confirm the absence of a dorsal shield to confirm the validity of *Neoraphignathus*.

Notes on the validity of *Raphignathus evidus*, *R. hsiufui*, and *R. johnstoni*

The taxonomic identity of *Raphignathus evidus* Fan, *R. hsiufui* Fan, and *R. johnstoni* Womersley are doubtful. These species were originally described based on single specimens, minor differential characteristics (i.e. number of dorsal setae on the lateral prodorsal shield; all three species have two pairs of setae on lateral shields), and small opisthosomal shields. In contrast, all other *Raphignathus* species have three pairs of setae on the lateral prodorsal shields along with the pores (ia). The immature stages of *Raphignathus* gradually develop the prodorsal shields, striation patterns, and leg setae (Fan and Yin 2000). For instance, the immature stages of *R. giselae*, *R. lenis*, and *R. caspicus* each have two setae on the lateral prodorsal shields (three setae in adult) and small lateral prodorsal shields with weakly developed striations. Moreover, we also observed the immatures from more than 10 populations of *Raphignathus* and found reduced size of weakly sclerotized lateral prodorsal shields and setae set on the edges of shields. Based on this evidence, *R. evidus*, *R. hsiufui*, and *R. johnstoni* should be revised and more specimens collected to confirm their validity.

New species

Raphignathus (Diraphignathus) neohecmatanaensis sp. nov.

<https://zoobank.org/12E13CEE-478F-4A3F-A47E-B3C7F34C73FA>

Figs 1–8

Diagnosis. Female: endopodal shield absent between coxae I–IV; two small shields present posterolateral to median prodorsal shield; palp femora with two setae; femora 6–5–3–2; genua 5(+κ)-5(+κ)-4–4; tibiae 5(+φρ)-5(+φρ)-4(+φρ)-4 (+φρ); tarsi 21(1ω)–20(1ω)-15–14.

Description. Female ($n = 4$). Idiosoma oval, length of body (including gnathosoma) 533 (525–545); width of body 345 (338–353).

Dorsum (Fig. 1). Propodosoma with one medial and two lateral shields each containing three setae; medial sclerite with setae vi , si and $c1$; paired ovoid lateral shields each with an eye, one cupule (ia) and sci , sce and seta $c2$ seta; opisthosomal setal pairs $d1$, $e1$ and the pair of cupuli (im); posterior opisthosomal shield large, rectangular, bearing four pairs of setae ($f1$, $h1$ – 3) and one pair of the cupule (ip); all dorsal shields finely punctate; dorsal body setae setiform, smooth and acute; pseudanal setae $ps1$ dorsally located. Lengths of dorsal setae: vi 25 (23–27), ve 28 (26–30), sci 27 (26–29), sce 28 (26–29), $c1$ 23 (17–19), $c2$ 25 (19–23), $d1$ 21 (20–23), $e1$ 22 (21–23), $f1$ 21 (19–22), $h1$ 24 (23–25), $h2$ 25 (23–25), $h3$ 22 (21–24), $ps1$ 23 (21–25); distances between dorsal 195 setae: vi – vi 27 (29–31), sci – sci 123 (118–128), vi – sci 70 (66–72), sce – $c2$ 68 (65–72), $c1$ – $c1$ 30 (28–32), $d1$ – $d1$ 99 (92–101), $c1$ – $d1$ 53 (49–55), $d1$ – $e1$ 22 (21–24), $f1$ – $f1$ 88 (83–90), $e1$ – $f1$ 65 (61–68), $h1$ – $h1$ 45 (42–48), $h1$ – $h2$ 43 (41–46), $h2$ – $h2$ 77 (72–80), $h3$ – $h3$ 101 (98–106).

Venter (Fig. 2). Venter entirely striated, without punctations; coxisternal shields absent (Fig. 2); ventral setae lengths: $1a$ 42 (41–44), $1b$ 38 (35–39), $1c$ 34 (33–36), $2b$ 36 (30–34), $2c$ 32 (30–34), $3a$ 24 (23–26), $3b$ 18 (17–20), $3c$ 36 (34–38), $4a$ 22 (23–27), $4c$ 38 (35–40); two pairs of aggenital setae ($ag1$ – 2) with one cupule (ih) on each side of the genital shield; anal opening and genital shields separate; genital shield prominent with a few punctations, bearing three pairs of genital setae ($g1$ – 3); anal opening terminal, with three pairs of setae ($ps1$ – 3), $ps1$ dorsal $ps3$ and $ps2$ ventral; ventral setal lengths: $ag1$ 29 (27–32); $ag2$ 27 (25–28); $g1$ 31 (28–33); $g2$ 25 (23–28); $g3$ 20 (19–22); $ps2$ 22 (21–23); $ps3$ 21 (20–22). Distances between ventral setae: $1a$ – $1a$ 55 (53–58), $3a$ – $3a$ 115 (97–109), $4a$ – $4a$ 70 (68–73), $ag2$ – $ag2$ 42 (41–43), $g1$ – $g1$ 38 (35–40), $g2$ – $g2$ 52 (48–55), $g3$ – $g3$ 75 (74–75), $2b$ – $2c$ 30 (25–29), $1a$ – $3a$ 50 (49–53), $3a$ – $4a$ 72 (68–75), $4a$ – $ag1$ 85 (82–88), $ag1$ – $ag2$ 65 (63–68), $ag2$ – $g1$ 63 (60–65), $g1$ – $g2$ 15 (14–17), $g2$ – $g3$ 22 (21–25), ag – $g1$ 42 (40–45), $g3$ – $ps3$ 16 (15–18), $ps2$ – $ps3$ 16 (14–18).

Gnathosoma (Figs 3, 4). Ventral infracapitular with two pairs of very long setae (m and n), m 40 (39–42), n 52 (49–54) and two pairs of pilose adoral setae ($or1$ – 2), $or1$ 23 (21–24), $or2$ 20 (19–22) (Fig. 3); stylophore conical and striated; palp chaetotaxy (femur-tarsus) as follows: 3–2–4+1 claw 4+1ω+4 eupathidia (ζ) (Fig. 4).

Legs (Figs 5–8). Length of legs I–IV (without coxae): 340 (328–348); 270 (276–286); 325 (317–328); 375 (367–384), respectively. Chaetotaxy on legs

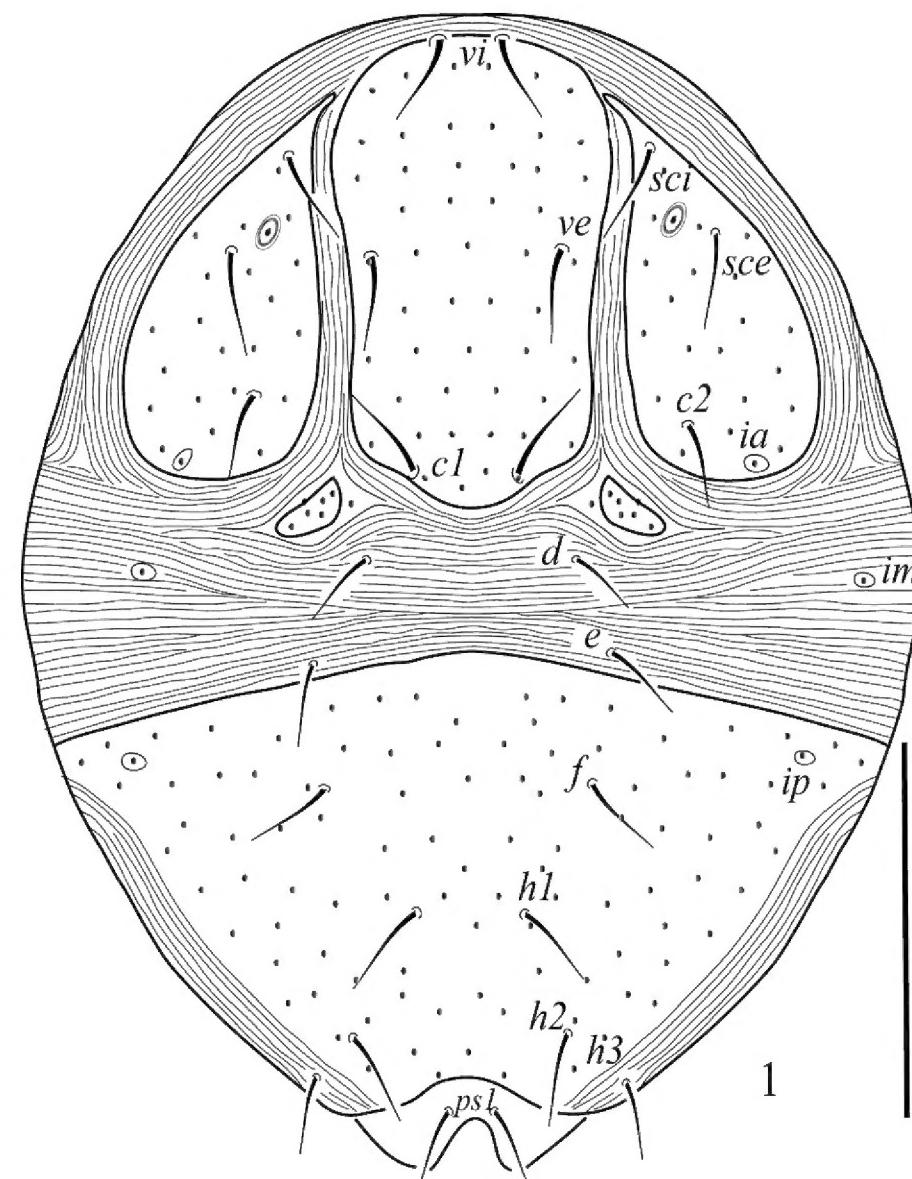


Figure 1. *Raphignathus (Diraphignathus) neohecmatanaensis* sp. nov. (female), dorsum.
Scale bar: 100 µm.

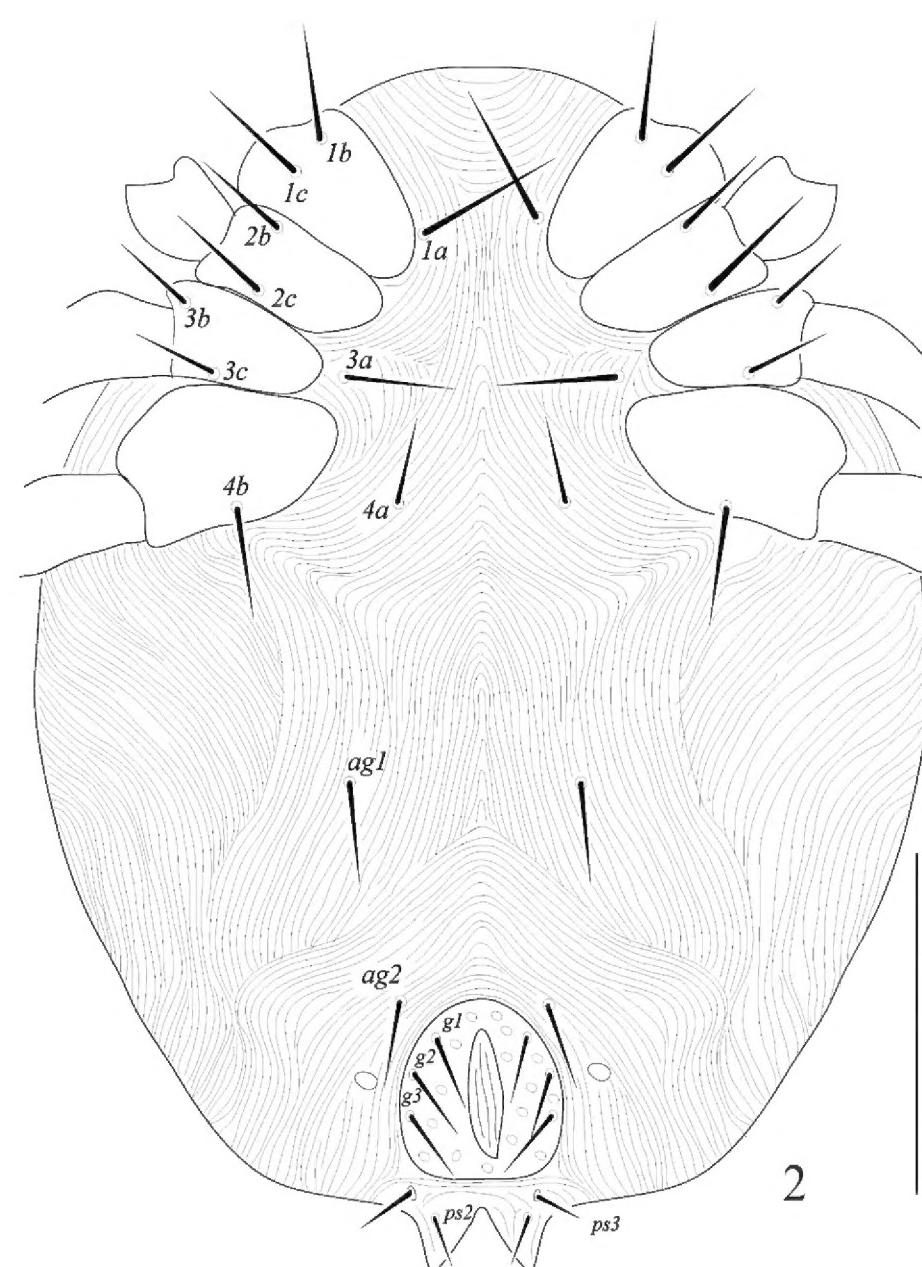


Figure 2. *Raphignathus (Diraphignathus) neohecmatanaensis* sp. nov. (female), venter.
Scale bar: 100 µm.

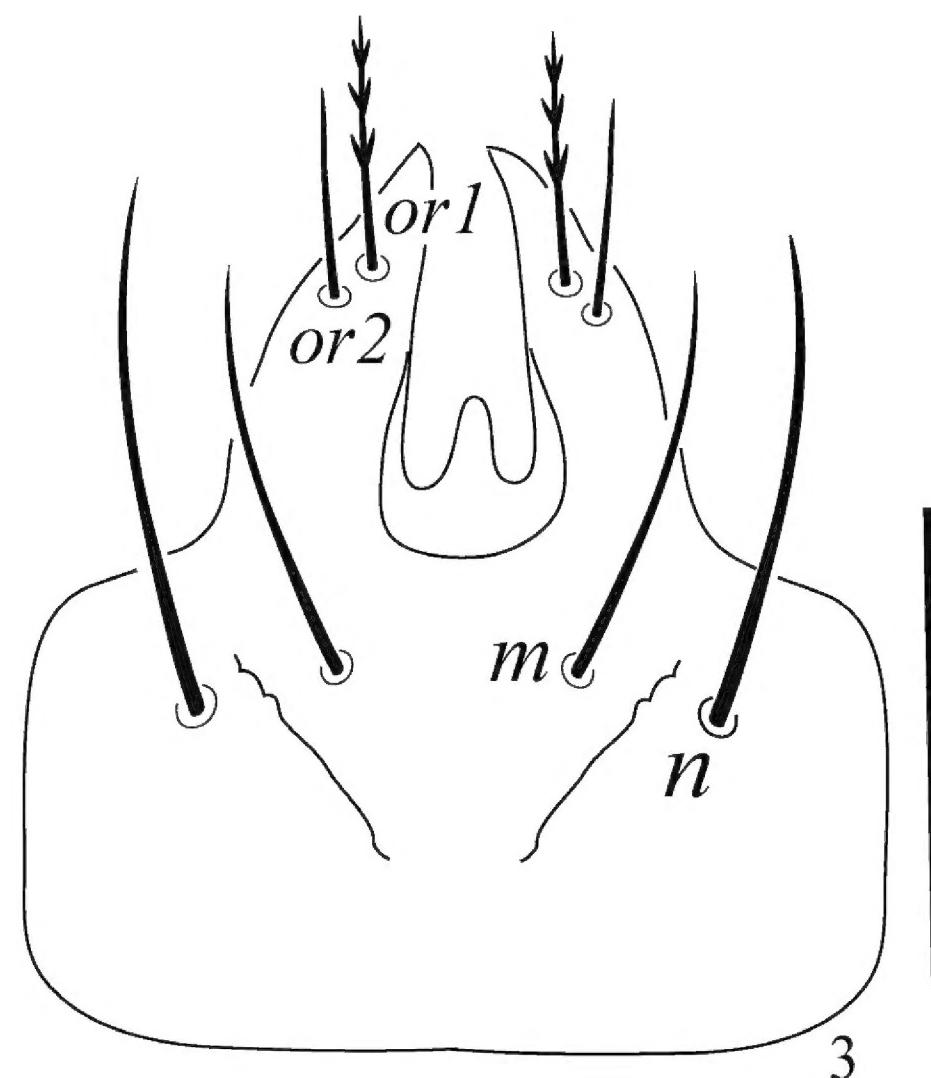


Figure 3. *Raphignathus (Diraphignathus) neohecmatanaensis* sp. nov. (female), gnathosoma. Scale bar: 50 µm.

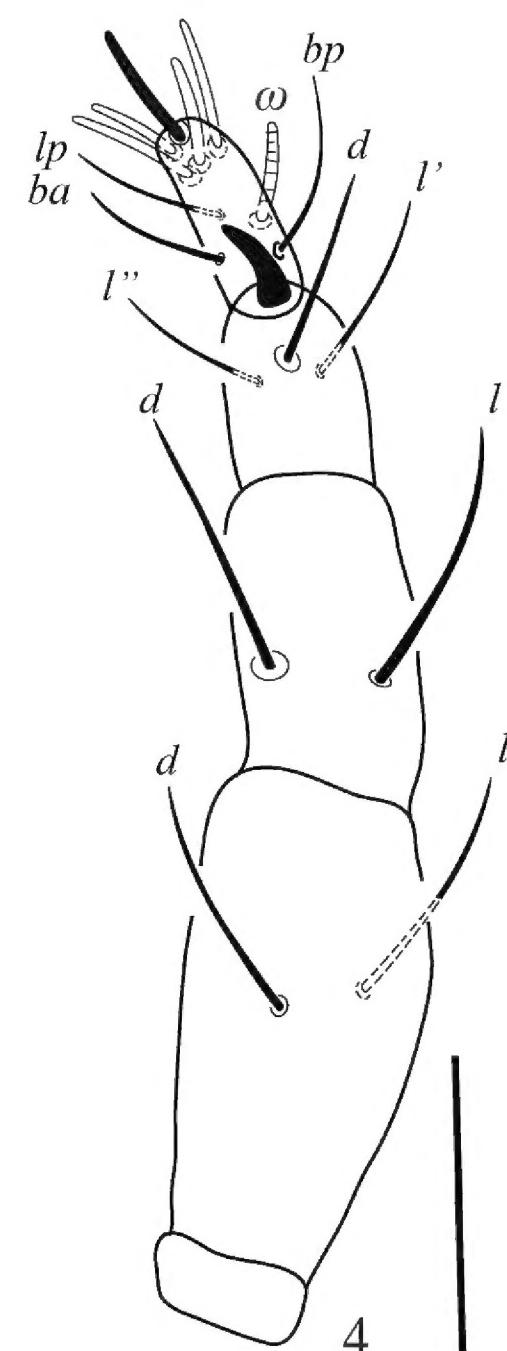
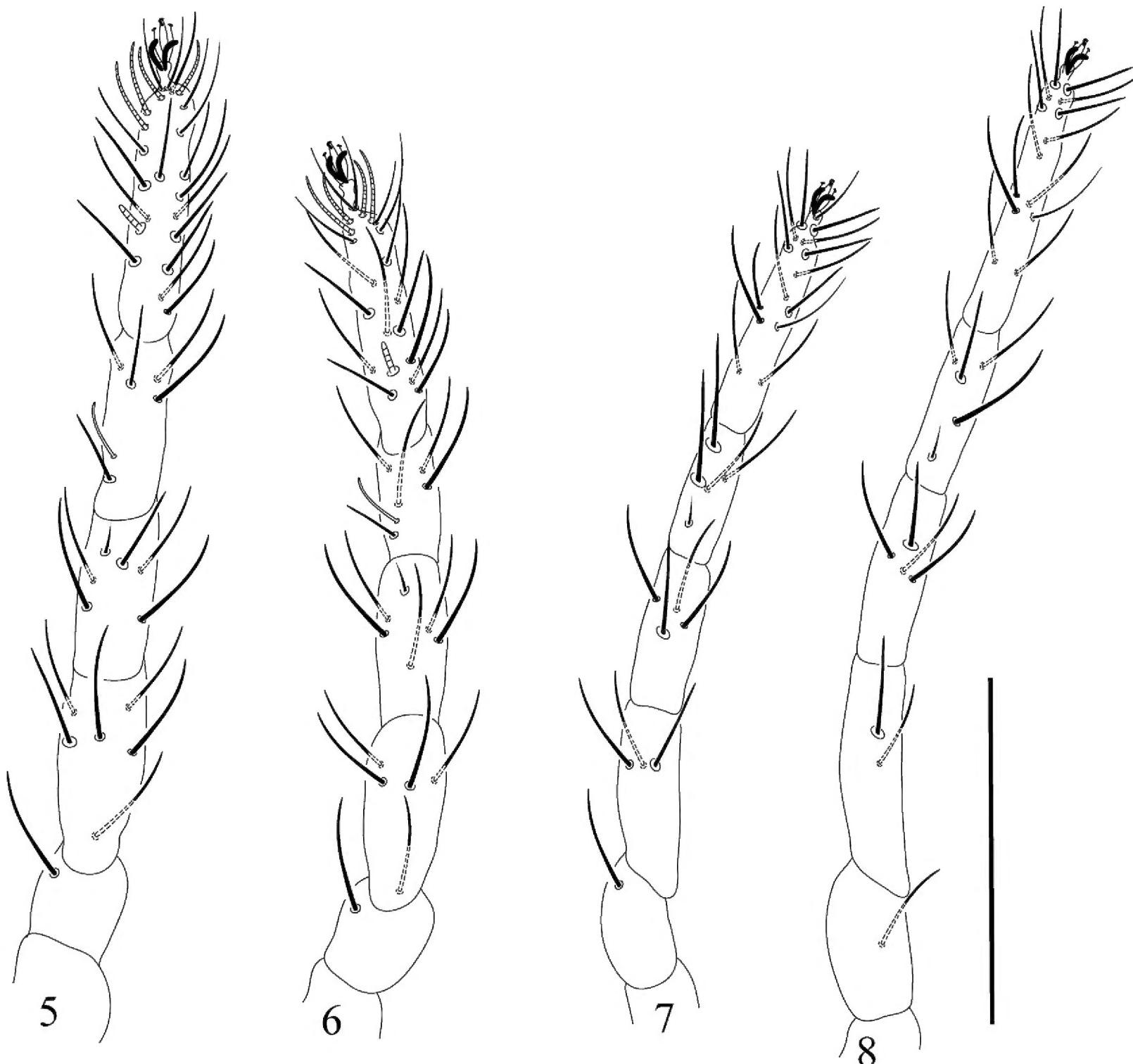


Figure 4. *Raphignathus (Diraphignathus) neohecmatanaensis* sp. nov. (female), palp. Scale bar: 20 µm.



Figures 5–8. *Raphignathus (Diraphignathus) neohecmatanaensis* sp. nov. (female), Legs I–IV. Scale bar: 20 µm.

I–IV (solenidia in parentheses and not included in setal counts): coxa 2–2–2–1; trochanter 1–1–2–1; femora 6–5–3–2; genua 5(+κ)-5(+κ)-4–4; tibiae 5(+φρ)-5(+φρ)-4(+φρ)-4(+φρ); tarsi 21(1ω)–20(1ω)–15–14.

Male and immature stages. Unknown.

Type materials. **Holotype** female and three paratype females, Faifa, Jazan, 24°30.412'N, 39°36.578'E, 8 Oct., 2020, collected from *Ziziphus spina-christi* Mill. (Rhamnaceae) by Eid M. Khan, Jawwad H. Mirza & Hafiz S. Mushtaq.

Etymology. The specific epithet is in reference to the similarity of the new species to *R. (D.) hecmatanaensis*; *neo* = new.

Remarks. *Raphignathus (D.) neohecmatanaensis* sp. nov., belongs to the subgenus *Diraphignathus* subgen. nov. The new species resembles to *R. (D.) hecmatanaensis* Khanjani & Ueckermann in having two pairs of setae (*d*1 and *e*1) on the interscutal membrane, two setae on the palp femora, and two small plates present posterolateral to the median prodorsal shield. However, the new species differs from *R. (D.) hecmatanaensis* in the absence of an endopodal shield (vs present), femur IV with two setae (vs three), and leg tarsus I with one solenidion (vs two solenidia).

Key to genera, subgenera, and all known species of the family Raphignathidae

Five species are not included in the key. *Raphignathus longimanus* (Koch), *R. impressus* (Koch), *R. hispidus* (Dugès), and *R. deserticula* (Trägårdh) because their descriptions are incomplete, and *R. lanuginosus* Atyeo is excluded, as it was described on the male.

- 1 Dorsum with well-developed shields, one medial, one pair of lateral shields on prodorsum and one hysterosomal shield..... **Genus *Raphignathus* [2]**
- Dorsum without shields.... **Genus *Neoraphignathus*, *N. howei* Smiley & Moser**
- 2 Interscutal membrane without setae, hysterosomal shield with six pairs of setae..... ***Raphignathus* (*Raphignathus*) subgen. nov. [3]**
- Interscutal membrane with ≥ 1 setae 13
- 3 Opisthosoma or opisthosomal shield reticulated 4
- Opisthosomal shield smooth or otherwise, not reticulated 6
- 4 Prodorsal shields reticulated.... ***R. (R.) crustus* Fan & Zhang, New Zealand**
- Prodorsal shields smooth or punctate 5
- 5 Tibia I with $5+2\varphi$, Tibia III with $5+1\varphi$, dorsal body setae comparatively long (54–74)
- ***R. (R.) kurdistaniensis* Nasrollahi, Khanjani & Mirfakhraei, Iran**
- Tibia I with $5+1\varphi$, Tibia III with $4+1\varphi$, dorsal body setae comparatively short (24–36) ***R. (R.) darjeelingensis* Gupta, India**
- 6 Opisthosoma without distinct shield; setae *d*1, *e*1, and *f*1 very minute, $1/3$ – $1/2$ length of setae *v*1 ***R. (R.) guajavae* Gupta, India**
- Opisthosoma with distinct opisthosomal shield; setae *d*1, *e*1, and *f*1 at least $2/3$ length of setae *v*1 7
- 7 Genu I and II each with a large leaf-like solenidion
- ***R. (R.) pycnonotus* (Gupta & Paul), India**
- Genu I and II each with a small, slender solenidion 8
- 8 Setae *c*1 short, reaching $1/3$ length of interscutal membrane, far behind the anterior margin of opisthosomal shield; tarsus IV with large solenidion..... ***R. (R.) inornata* (Gupta & Paul), India**
- Setae *c*1 crossing interscutal membrane and anterior margin of opisthosomal shield; tarsus IV with small solenidion 9
- 9 Tibia I with one solenidion 10
- Tibia I with two solenidia 12
- 10 Genu IV with three setae..... ***R. (R.) hirtellus* Athias-Henriot, Algeria**
- Genu IV with four setae..... 11
- 11 Ratios $d_1-d_1/c_1-c_1 = 3.00$, $c_2-c_2/d_1-d_1 = 3$, $d_1-d_1/e_1-e_1 = 0.58$, $e_1-e_1/f_1-f_1 = 0.94-1.00$ ***R. (R.) neocardinalis* Atyeo, The Bahamas**
- Ratios $d_1-d_1/c_1-c_1 = 6.00$, $c_2-c_2/d_1-d_1 = 1.22$, $d_1-d_1/e_1-e_1 = 1.38$, $e_1-e_1/f_1-f_1 = 0.65$ ***R. (R.) conspicuus* (Berlese), Colombia**
- 12 Dorsal setae comparatively long; setae *c*1, and *d*1 crossing bases of *d*1 and *e*1, respectively ***R. (R.) khorramabadensis* Bagheri, Jafari & Paktinat, Iran**
- Dorsal setae comparatively short; setae *c*1, and *d*1 far behind bases of *d*1 and *e*1, respectively..... ***R. (R.) cardinalis* (Ewing), USA**

- 13 Interscutal membrane with one pair of setae.....
.....*Raphignathus (Monoraphignathus) subgen. nov. [14]*

– Interscutal membrane with more than one pair of setae 27

14 Palp femur with two setae; femur I with three setae
.....*R. (M.) arabicus Gomaa & Hassan, Egypt*

– Palp femur with three setae; femur I with five or six setae..... 15

15 Femur IV with two or three setae 16

– Femur IV with four setae..... 21

16 Femur IV with two setae 17

– Femur IV with three setae 19

17 Genu II with five setae including micro setae.....
.....*R. (M.) costatus Chaudhri, Akbar & Rasool, Pakistan*

– Genu II with six setae including microsetae 18

18 Setae e1 reaching to bases of h1; dorsal body setae with spinules along entire length.....*R. (M.) zhaoi Hu, Jing & Liang, China*

– Setae e1 reaching half distance to bases of h1 (or distance e1–h1), dorsal body setae with spinules along entire length

.....*R. (M.) kuznetzovi Dogan & Ayyildiz, Turkey*

19 Setae c2 crossing bases of d1, Setae c1 extending to bases of e1, setae e1 extending to bases of h1*R. (M.) ueckermannii Koç & Kara, Turkey*

– Setae c2 crossing setae c1 far behind to the bases of e1, setae e1 far behind to the bases of h1 20

20 Dorsal body setae ensiform, setae c1 far behind bases of d1, d1–d1 distance almost five times more than c1–c1 distance.....
.....*R. (M.) ensipilosus Meyer & Ueckermann, South Africa*

– Dorsal body setae setiform, setae c1 far behind bases of d1, d1–d1 distance almost equal to c1–c1*R. (M.) cometes Atyeo, Bahama-Islands*

21 Small shields absent posterolateral to median prodorsal shield..... 22

– Small shields present posterolateral to median prodorsal shield..... 25

22 Genital plates/covers with four pairs of setae

.....*R. (M.) koseiensis Dönel & Doğan, Turkey*

– Genital plates/covers with three pairs of setae 23

23 Femur I and II each with five setae...*R. (M.) solimani Hassan & Gomaa, Egypt*

– Femur I and II each with six setae 24

24 Dorsal setae comparatively long; most setae cross base of next consecutive setae.....*R. (M.) kelkitensis Dönel & Doğan, Turkey*

– Dorsal setae comparatively short; most setae far behind base of next consecutive setae.....*R. (M.) fani Doğan & Ayyildiz, Turkey*

25 Dorsal setae comparatively long; most setae reach or cross base of next consecutive setae*R. (M.) bathursti Meyer & Ryke, South Africa*

– Dorsal setae comparatively short; most setae far behind base of next consecutive setae..... 26

26 Trochanter III with three setae.....*R. (M.) afyonensis Akyol & Koç, Turkey*

– Trochanter III with two setae

.....*R. (M.). collegiatus Atyeo, Baker, & Crossley, USA*

27 Interscutal membrane with two pairs of setae.....
.....*R. (Diraphignathus) subgen. nov. [28]*

– Interscutal membrane with three or four pairs of setae

.....*R. (Triraphignathus) subgen. nov. [60]*

- 28 Medial prodorsal shield with two pairs of setae 29
 – Medial prodorsal shield with three pairs of setae 30
 29 Setae *c1* present, setae *vi* absents; presence of plates behind the anteromedian plate; femur IV with 2 setae
 *R. (D.) evansi* Zaher & Gomaa, Egypt
 – Setae *c1* absent, setae *vi* present; dorsum without a pair of small plates behind anteromedian plate; femur IV with 3 setae
 *R. (D.) ehari* Zaher & Gomaa, Egypt
 30 Genital plates/covers with four pairs of setae 31
 – Genital plates/covers with three pairs of setae 32
 31 Two small shields posterior to median prodorsal shield absent; endopodal shields absent; setae *f1* behind the anterior margin of opisthosomal shield *R. (D.) saboorii* Ghorbani & Bagheri, Iran
 – Two small shields posterior to median prodorsal shield present; endopodal shields present; setae *f1* on the anterior margin of opisthosomal shield *R. (D.) karabagiensis* Akyol & Koç, Turkey
 32 Palp femur with two setae 33
 – Palp femur with three setae 44
 33 Two small shields posterior to median prodorsal shield present 34
 – Two small shields posterior to median prodorsal shield absent 38
 34 Endopodal shield present; femur IV with three setae 35
 – Endopodal shield absent; femur IV with two setae 36
 35 Tarsus I with two solenidia
 *R. (D.) hecmatanaensis* Khanjani & Ueckermann, Iran
 – Tarsus I with one solenidion *R. (D.) arcus* Akyol, Turkey
 36 Femur IV with two setae; tarsus I with one solenidion
 *R. (D.) neohecmatanaensis* sp. nov. Alatawi & Kamran, Saudi Arabia
 – Femur IV with three setae; tarsus I with two solenidia 37
 37 Lateral prodorsal shield with one pair of pob; tibiae III 5(+1φp) tarsi 18(+1ω+1ω2) *R. (D.) seraji* Pishehvar & Khanjani, Iran
 – Lateral prodorsal shield without pob; tibiae III 5 tarsi 19(+1ω+1ω2)
 *R. (D.) rakhshandehi* Pishehvar & Khanjani, Iran
 38 Dorsal setae distally forked or tricarinate
 *R. (D.) furcisetosus* Meyer & Ueckermann, South Africa
 – Dorsal setae simple, not distally forked or tricarinate 39
 39 Femur IV with two setae *R. (D.) erzincanica* Doğan, Turkey
 – Femur IV with three setae 40
 40 Opisthosomal shield reduced; interscutal membrane more longer than opisthosomal shield 41
 – Opisthosomal shield equally long or longer than interscutal membrane 43
 41 Dorsal setae stout, serrate and blunt-tipped
 *R. (D.) membranus* Fan & Yin, China
 – Dorsal setae simple, distally pointed 42
 42 Interscutal membrane four times longer than much reduced opisthosomal shield; *f1* on anterior margin of opisthosomal shield
 *R. (D.) vahiti* Doğan, Turkey
 – Interscutal membrane slightly longer than opisthosomal shield; *f1* behind anterior margin of opisthosomal shield
 *R. (D.) giselae* Meyer & Ueckermann, Zimbabwe

- 43 Median prodorsal shield anteriorly extending to peritremes and wider anteriorly near setae *sci* as compared to posterior half; setae *f1* on anterior margin of opisthosomal shield..... ***R. (D.) gracilis* (Rack), Germany**
- Median prodorsal shield anteriorly far behind peritremes and almost equally wide anteriorly near setae *sci* and at posterior half; setae *f1* just behind anterior margin of opisthosomal shield ***R. (D.) bakeri* Zaher & Gomaa, Egypt**
- 44 Small shields posterior to median prodorsal shield absent 49
- Two small shields posterior to median prodorsal shield present 45
- 45 Coxae II with one seta ***R. (D.) atyeoi* Meyer & Ueckermann, South Africa**
- Coxae II with two setae 46
- 46 Femur IV with two setae 47
- Femur IV with three setae 48
- 47 Coxae III and IV with endopodal shields; setae *f1* on posterior margin of interscutal membrane; distance $f1-f1 < d1-d1$ ***R. (D.) summersi* Robaux, USA**
- Coxae III and IV without endopodal shields; setae *f1* far behind posterior margin of interscutal membrane; distance $f1-f1 > d1-d1$
..... ***R. (D.) aciculatus* Fan, China**
- 48 Tarsus I–IV 19+ω, 15+1ω, 13, 12
..... ***R. (D.) africanus* Meyer & Ueckermann, South Africa**
- Tarsus I–IV 21+1 ω, 21+1ω, 15, 14
..... ***R. (D.) hatamii* Khanjani & Pishehvar, Iran**
- 49 Coxa II with one seta ***R. (D.) rarus* Kuznetsov, USSR**
- Coxa II with two setae 50
- 50 Coxae III and IV without endopodal shields 51
- Coxae III and IV with endopodal shields 53
- 51 $c1-f1/f1-f1 = 0.70$; $c1-f1 < f1-f1$; space between setae *f1-f1* twice as wide as between setae *d1-d1* ***R. (D.) atomatus* Fan & Zhang, New Zealand**
- $c1-f1/f1-f1 = 1.50-1.87$; $c1-f1$ 1.5–2.0 times more than *f1-f1*; distance $f1-f1 \leq d1-d1$ 52
- 52 Dorsal setae barbed; setae *c1*, *d1*, and *e1* reach or cross bases of next consecutive setae, distances $d1-f1 \leq f1-f1$; setae *f1* near anterior margin of opisthosomal shield ***R. (D.) satoi* Shiba, Malay Peninsula**
- Dorsal setae simple; setae *c1*, *d1*, and *e1* not reaching base of next consecutive seta; distances $d1-f1$ 1.31 times more as *f1-f1*, *f1* behind anterior margin of opisthosomal shield.....
..... ***R. (D.) kamiensis* Meyer & Ueckermann, South Africa**
- 53 Femur I and II with five and four setae, respectively
..... ***R. (D.) hexeris* Chaudhri, Akbar & Rasool, Pakistan**
- Femur I and II with six and five setae, respectively 54
- 54 Opisthosomal shield 2–4 times wider than interscutal membrane 55
- Interscutal membrane as wide as or more wider than opisthosomal shield 56
- 55 Setae *c1* far behind posterior margin of prodorsal shield; tibia III with five setae excluding solenidion; opisthosomal shield four times wider than interscutal membrane ***R. (D.) neogracilis* Robaux, USA**
- Setae *c1* on the posterior margin of prodorsal shield; tibia III with four setae excluding solenidion; opisthosomal shield twice as wide as interscutal membrane ***R. (D.) scutatus* Kuznetsov, USSR**

56	Femur IV with two setae	57
-	Femur IV with three setae.....	59
57	Dorsal shields without striations, tarsus I with 22 setae	
	.....<i>R. (D.) tumidus</i> Kuznetsov, USSR	
-	Dorsal shields with fine, sparse puncta and faint striae; tarsi I with 21 setae.....	58
58	Tarsi III–IV with 14 and 13 setae, respectively; femur II with five setae	
	.....<i>R. (D.) caspicus</i> Doustaresharaf and Kazemi, Colombia	
-	Tarsi III–IV with 15 and 14 setae, respectively; femur II with six setae	
	.....<i>R. (D.) tamaricis</i> Poudineh, Ramroodi & Bagheri, Iran	
59	Setae $f_1-f_1 \leq c_1-c_1$ and d_1-d_1 <i>R. (D.) giresuniensis</i> Doğan, Turkey	
-	Setae f_1 twice as widely spaced as c_1-c_1	
	.....<i>R. (D.) orientalis</i> Fan & Li, China	
60	Medial prodorsal shield with two pairs of setae	
	.....<i>R. (T.) lenis</i> Barillo, Uzbekistan	
-	Medial prodorsal shield with ≥ 3 pairs of setae	61
61	Genital shield with four pairs of setae	62
-	Genital shield with three pairs of setae.....	63
62	Two small shields present posterolateral to prodorsal shield; endopodal shields near coxae III and IV absent	
	.....<i>R. (T.) sceptrum</i> Chaudhri, Akbar & Rasool, Pakistan	
-	Small shields absent posterolateral to prodorsal shield; endopodal shields near coxae III and IV present.....	
	.....<i>R. (T.) quadrigeminus</i> Dönel & Doğan, Turkey	
63	Palp femur with three setae.....	
	.....<i>R. (T.) aethiopicus</i> (Meyer & Ryke), South Africa	
-	Palp femur with two setae	64
64	Femur IV with two setae	
	.....<i>R. (T.) karrooi</i> Meyer & Ueckermann, South Africa	
-	Femur IV with three setae	65
65	Femur I with five setae, femur II with four setae	
	.....<i>R. (T.) domesticus</i> Shiba, Japan	
-	Femur I with six setae, femur II with five setae	66
66	Two small shields present posterolateral to prodorsal shield	67
-	Small shields absent posterolateral to prodorsal shield	68
67	Tibiae III with four setae, solenidia absent	
	.....<i>R. (T.) hamooniensis</i> Poudineh, Ramroodi & Bagheri, Iran	
-	Tibiae III with five setae with one solenidion.....	
	.....<i>R. (T.) larestanensis</i> Bagheri, Akrami & Majidi, Iran	
68	Genu II with four tactile setae; endopodal shields near coxae I–II present	
	.....<i>R. (T.) emirdagiensis</i> Akyol & Koç, Turkey	
-	Genu II with five tactile setae; endopodal shields near coxae I–II absent	
	.....<i>R. (T.) ozkani</i> Doğan, Turkey	

Discussion

The taxonomic classification of predatory mites of the genus *Raphignathus* are revised, and for the first time, the genus is divided into four subgenera by con-

sidering the morphologically valid, persistent, and prominent characters (Atyeo 1963). The use of subgenera supports the identification of raphignathoid species and will help to avoid designation of new species based on variable characters. *Raphignathus evidus*, *R. hsiufui*, and *R. johnstoni* are considered doubtfully valid. They were described based on size of lateral prodorsal shields and number of setae, but these in these characteristics they resemble immature stages (Fan and Yin 2000). The monotypic genus *Neoraphignathus* was erected based on only the single type specimen with a restricted geographical region and its description is brief. We suspect it might have been described based on the immature stage of a *Raphignathus* species, and we suggest that the type species be revised and more specimens collected to confirm the validity of the species and genus.

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The authors have declared that no competing interests exist.

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Data availability

All of the data that support the findings of this study are available in the main text.

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